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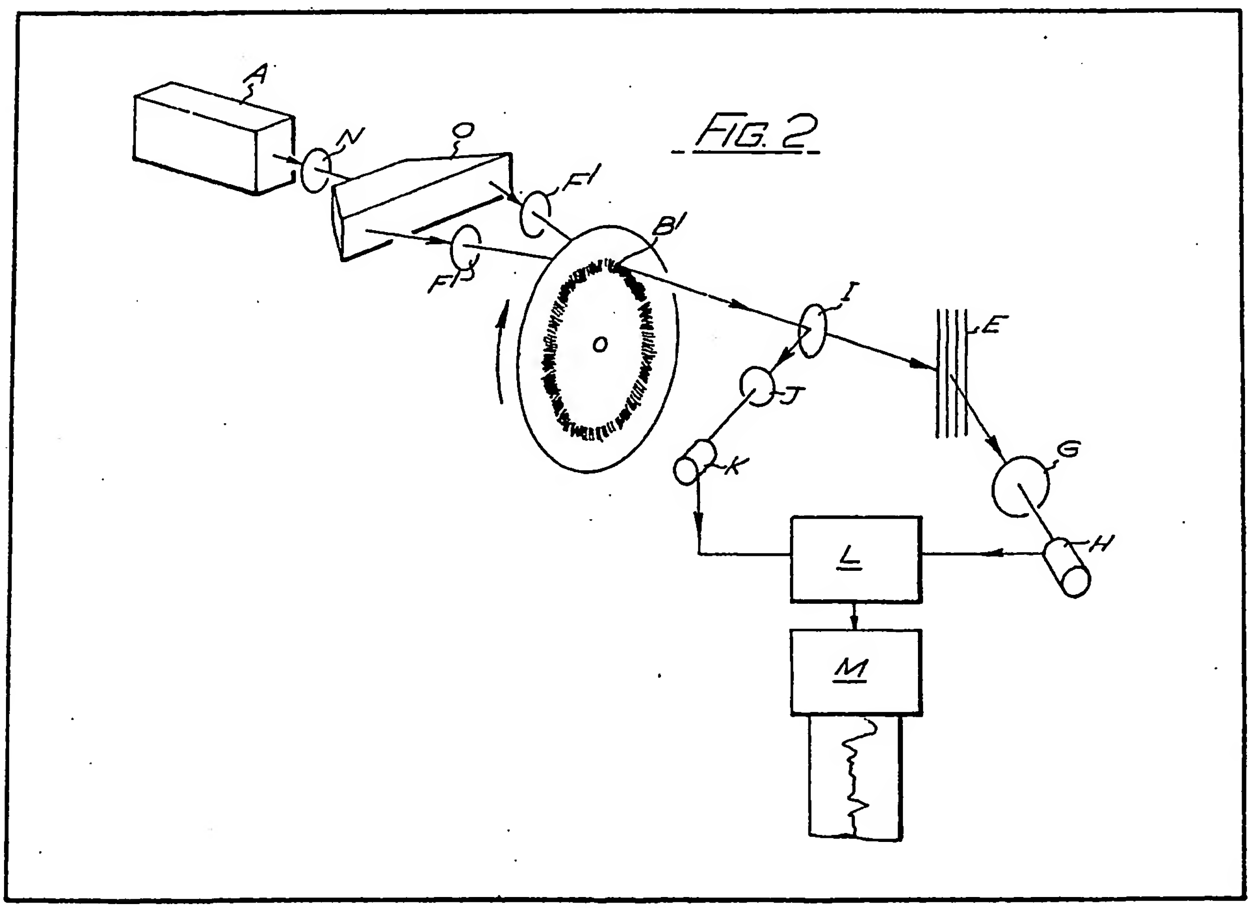
(54) Apparatus for Continuously Measuring Optical Retardation of Synthetic Filaments or Film

(57) Apparatus for continuously measuring the optical retardation of synthetic filaments E or film comprises source A of unpolarised or circularly polarised monochromatic light N, beam splitter O for creating two convergent beams, dichroic filters F′ with polarisation planes at right angles to each other and through which the beams pass to rotating radial diffraction grating B′ on a disc of transparent material at which the beams meet, the angle of convergence of the beams being such that the frequency-shifted first-order diffracted beams from the grating are coaxial.

Alternatively a single beam irradiates the grating to produce two divergent beams which are focused by a lens on to a stationary grating where they are combined. The dichroic filters are then located between the lens and stationary grating.

Reference and measurement beat frequency signals are generated by sampling the coaxial first-order diffracted beams before and after filaments E and are compared by phasemeter L.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.



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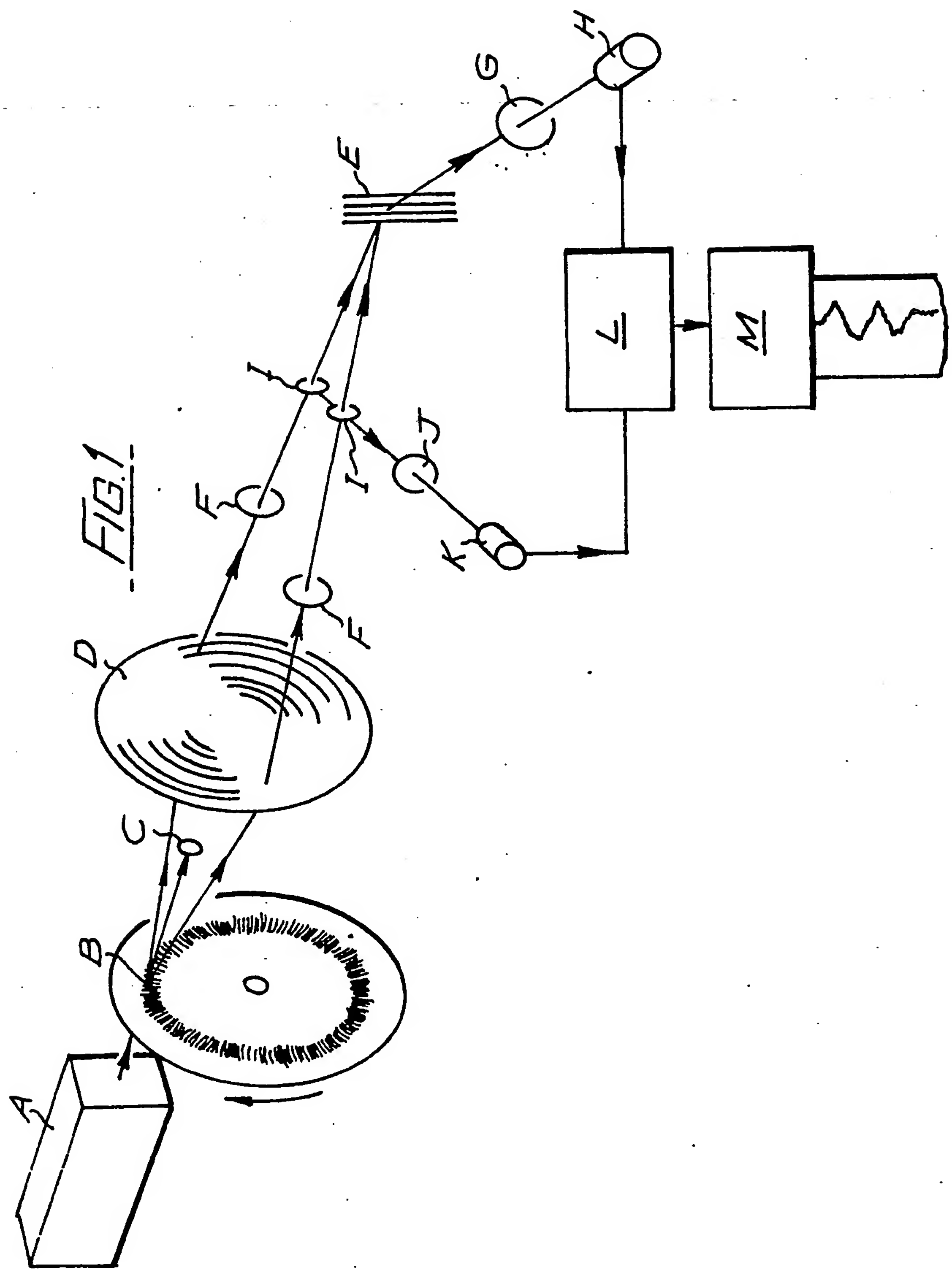

FIG.1

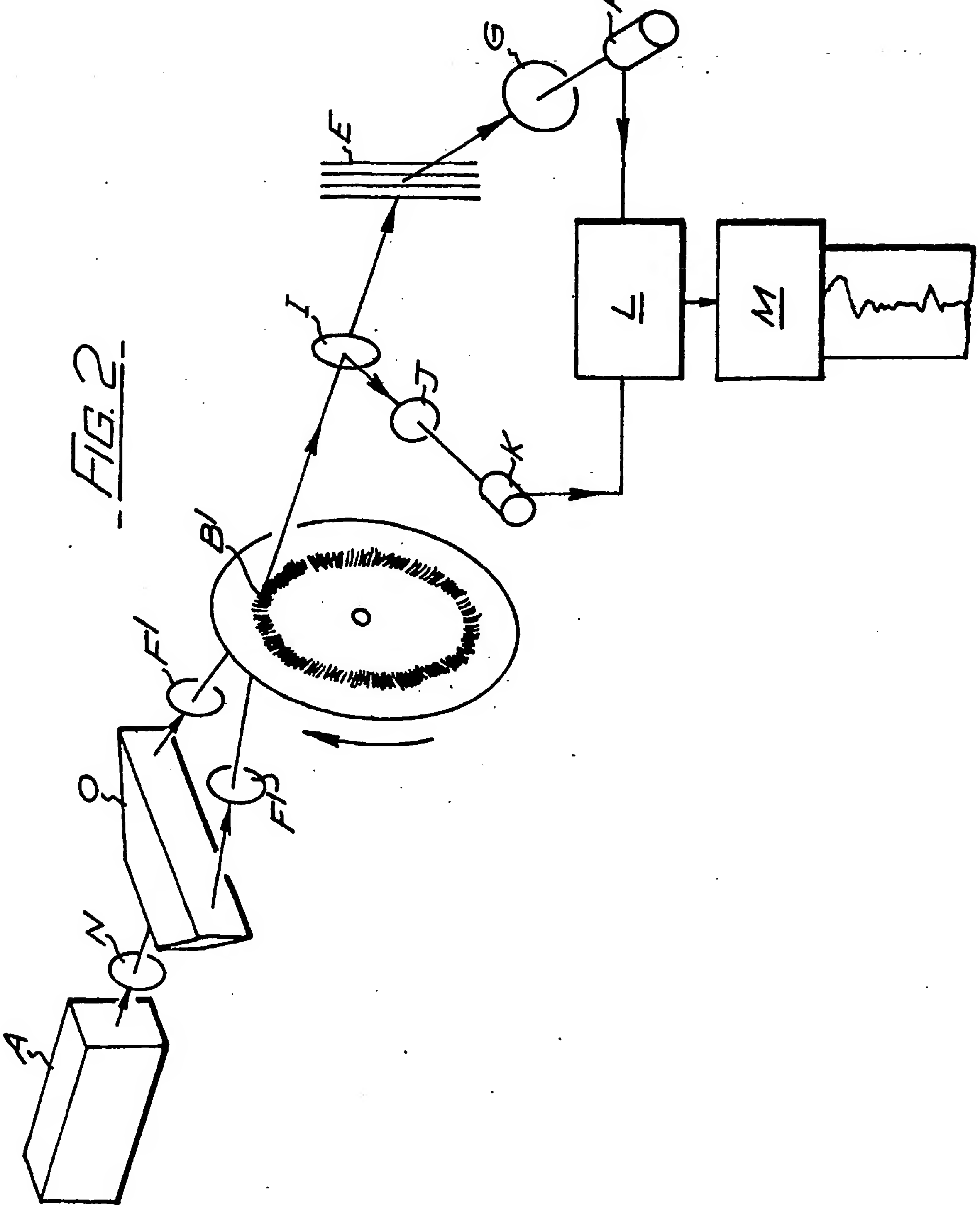

FIG. 2

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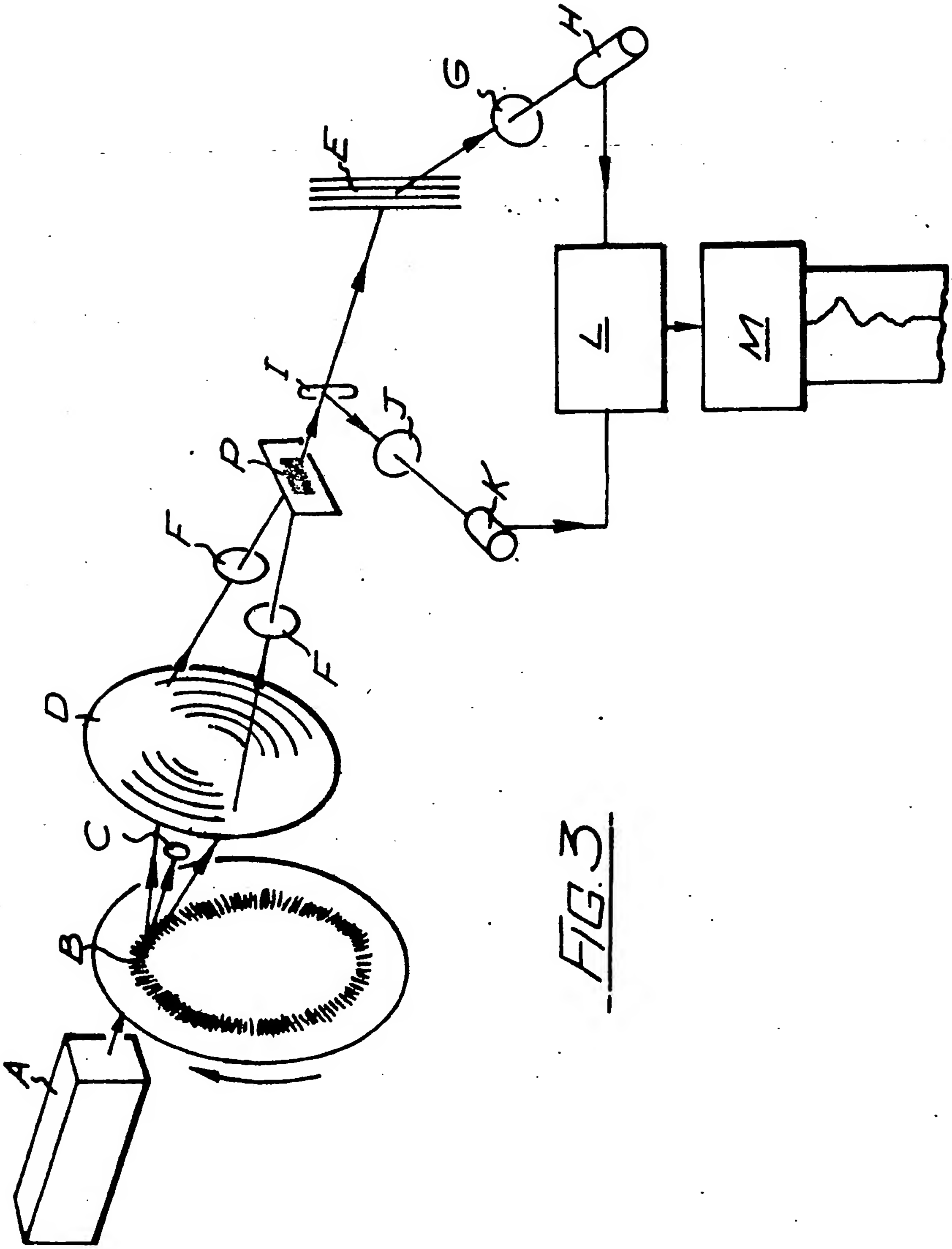

FIG.3

SPECIFICATION

Method and Apparatus for Continuously Measuring the Optical Retardation of Synthetic Filaments or Film

This invention relates to methods and apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film and producing a signal dependent on the optical retardation which may be used to control one or more associated process parameters. For example, in the melt spinning of a synthetic polyester filament yarn, such a signal may be used to control the speed at which the yarn is wound up in dependence on the birefringence of the wound filaments.

In order to overcome the disadvantages of known methods of monitoring birefringence changes, such as dependence on mechanical servo-systems with slow response times which make them incapable of relatively short yarn length examination, it has been proposed to pass continuously variable polarised light through the filaments or film, monitoring the state of polarisation of light refracted by the filaments or film, and measuring any relative change that occurs in that state. Preferably, two coherent orthogonally plane polarised monochromatic light beams which are colinear and with slightly different light frequencies are allowed to fall on a yarn in the form of a single filament ribbon, and light deviated by refraction at the filaments then passes through a dichroic filter, e.g., a Polaroid (Registered Trade Mark) filter, with its plane polarisation at 45° to the planes of polarisation of the two beams, and on to a photodetector, the electrical signal from which is thus a beat frequency equal to the difference between the two light frequencies. A reference beat frequency is obtained from unrefracted light and the phase difference between the two beat frequency signals (which phase difference is directly related to the retardation of the light passing through the filament ribbon) is measured by an electronic phasemeter from which an analogue voltage is obtained to operate a chart recorder or provide a feedback signal for control purposes.

In one apparatus for carrying out the proposed method means for generating continuously variable polarised light comprises a laser source, a first quarter wave plate, a rotating disc of dichroic material, e.g., a Polaroid (registered Trade Mark) filter, and a second quarter-wave plate. The disc and second quarter-wave plate form a continuously shifting de Senarmont compensator producing a continuous linearly changing retardation, and reference will hereafter be made to "the de Senarmont system".

The reference beat frequency signal may be obtained by sampling the incident beams before they reach the filaments and passing the light through a fixed dichroic filter to a photodetector, but it is thought more convenient to generate this signal by passing an independent light beam through the rotating disc and a separate quarter-wave plate to a photodetector.

It has been proposed to replace the de Senarmont system by an electro-optic assembly which has the advantage that higher beat frequencies can be generated and hence a faster response time for the phasemeter can be obtained but a limit is set by the "fly-back" time of the applied voltage.

It has also been proposed to replace the de Senarmont system by a rotating radial diffraction grating on a disc of transparent material, stop the emergent zero order diffracted beam with a beam stop, pass the two first-order beams (which are frequency shifted, one up and one down by an amount given by Nf, where N is the number of lines and f is the frequency of rotation) through dichroic filters to set their planes of polarisation parallel and perpendicular respectively to the threadline under investigation, and combine the two beams at the threadline. The advantage of this system is the ease with which relatively large frequency differences between the two beams can be generated by increasing the frequency of rotation of the grating and hence short response times obtained. However, since the two beams are not coaxial and have to be converged by a lens on to the threadline, the positioning of the threadline is critical and collection of the emergent light is made more complicated than with the de Senarmont system.

The primary object of the present invention is to overcome the disadvantages of the last mentioned system.

According to one aspect of the present invention, therefore, apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film comprises a source of unpolarised or circularly polarised monochromatic light, a beam splitter for splitting the light from the source and converting it into two convergent beams, a pair of dichroic filters with polarisation planes at right angles to each other and through which the two convergent beams pass to a rotating radial diffraction grating on a disc of transparent material at which the beams meet, the angle of convergence of the beams being such that the frequency-shifted first-order diffracted beams from the grating are coaxial.

Thus, while still taking advantage of the ease with which relatively large frequency differences between the two first-order diffracted beams can be generated by increasing the frequency of rotation of the grating, the "splitter" system does not suffer from criticality of the positioning of the threadline or complication in the collection of the emergent light.

A reference beat frequency signal may be generated by sampling the coaxial first-order diffracted beams before they reach the filaments and passing the light through a fixed dichroic filter with its plane of polarisation at 45° to the planes of the polarisation of both beams, and to a photodetector, the light deviated by refraction at

the filaments being passed through a similar dichroic filter and on to a photodetector, and the phase difference between the two beat frequency signals being measured by an electronic phasemeter.

According to a second aspect of the present invention, apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film comprises a source of unpolarised or circularly polarised monochromatic light, a rotating radial diffraction grating on a disc of transparent material upon which the beam of light is directed, a beam stop for the emergent zero order diffracted light, a pair of dichroic filters for the two emergent first-order beams (which have been frequency shifted, one up and one down) to set their planes of polarisation parallel and perpendicular respectively to the threadline or film under investigation, means for focussing the two beams on a stationary linear diffraction grating on transparent material, which combines the beams and from which they are directed to the threadline or film, a dichroic filter mounted with its plane of polarisation at an angle of 45° to the planes of polarisation of the two beams refracted by the filaments or film and detector means therefor, means for sampling the first-order diffracted beams before they reach the filaments or film, a dichroic filter with its plane of polarisation at an angle of 45° to the planes of polarisation of the sampled beams and detector means therefor, and an electronic phasemeter for measuring the difference between the two beat frequency signals generated by the detector means.

The rotating radial diffraction grating constitutes a beam splitter with divergent beams, which may be focussed by a lens, preferably before the beams pass through the pair of dichroic filters.

Both aspects of the invention will now be described, by way of example only of possible embodiments, with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic illustration of a prior proposal;

Figure 2 is a diagrammatic illustration of an embodiment of the first aspect of the invention; and

Figure 3 is a diagrammatic illustration of an embodiment of the second aspect of the invention.

In Figure 1 a laser A sends a monochromatic beam on to a rotating radial diffraction grating B, and the transmitted zero-order diffracted light is collected by a beam stop C. The two first-order diffracted beams (which have been frequency shifted, one up and one down) diverge to a lens D which focusses the beams on to filaments E. However, Polaroid (Registered Trade Mark) filters F polarise the converging beams, one being polarised parallel to the filaments and the other perpendicular to them. The two beams are refracted by the filaments E and the light passes through a Polaroid filter G having its plane of polarisation set at 45° to the planes of polarisation of the beams, and then is collected by a photodetector H.

A pair of plain glass reflectors I reflect small fractions of the two polarised beams to form a coaxial beam which is directed through a Polaroid filter J with its plane of polarisation at 45° to the other two. This coaxial beam is then collected by a photodetector K, and the beat frequency signal from the photodetector H is compared with the reference beat frequency signal from the photodetector K by an electronic phasemeter L and the difference between them converted to an analogue output to a recorder M.

The converging of the two beams at the filaments calls for precise positioning of the apparatus in relation to the filaments, while the different directions of the two beams means that their path lengths through the filaments will be different, thus complicating subsequent analysis of their behaviour.

The embodiment of the first aspect of the invention which is shown in Figure 2 is one way of overcoming these disadvantages. In this embodiment, the beam from a laser A is passed through a quarter-wave plate N to produce circularly-polarised light, which a beam splitter O divides into two equal-intensity beams converging on a rotating radial diffraction grating B′. However, the converging beams first pass through a pair of dichroic filters F-3 with polarisation planes at right angles to each other. The angle of convergence of the beams is such that the frequency-shifted first-order diffracted beams from the grating B′ are coaxial, and so the apparatus does not have to be precisely positioned in relation to the filaments E, and a single plain glass reflector I serves for directing a sample to the photodetector K. Otherwise, the latter part of the apparatus is the same as in Figure 1.

The embodiment of the second aspect of the invention which is shown in Figure 3 is a modification of the prior proposal of Figure 1 to get the same overall effect as with the embodiment of Figure 2. In Figure 3 the components A, B, C, D and F function exactly the same as in Figure 1, but instead of the filaments E being at the point of convergence of the beams a stationary linear diffraction grating P on the transparent material is positioned there so as to combine the beams into a coaxial beam as in Figure 2, and the components G to M inclusive in Figure 3 function exactly the same as in Figure 2.

Claims

1. Apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film comprising a source of unpolarised or circularly polarised monochromatic light, a beam splitter for splitting the light from the source and converting it into two convergent beams, a pair of dichroic filters with polarisation planes at right

angles to each other and through which the two convergent beams pass to a rotating radial diffraction grating on a disc of transparent material at which the beams meet, the angle of convergence of the beans being such that the frequency-shifted first-order diffracted beams from the grating are coaxial.

2. Apparatus as in Claim 1, wherein a refernce beat frequency signal is generated by sampling the coaxial first-order diffracted beams before they reach the filaments and passing the light through a fixed dichroic filter with its plane of polarisation at 45° to the planes of polarisation of both beams, and to a photodetector, the light deviated by refraction at the filaments being passed through a similar dichroic filter and on to a photodetector, and the phase difference between the two beat frequency signals being measured by an electronic phasemeter.

3. Apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film comprising a source of unpolarised or circularly polarised monochromatic light, a rotating radial diffraction grating on a disc of transparent material upon which the beam of light is directed, a beam stop for the emergent zero order diffracted light, a pair of dichroic filters for the two emergent first-order beams to set their planes or polarisation parallel and perpendicular respectively to the threadline or film under investigation, means for focussing the two beams on a stationary linear diffraction grating on transparent material, which combines the beams and from which they are directed to the threadline or film, a dichroic filter mounted with its plane of polarisation at an angle of 45° to the planes of polarisation of the two beams refracted by the filaments of film and detector means thereor, means for sampling the first-order diffracted beams before they reach the filaments or film, a dichroic filter with its plane of polarisation at an angle of 45° to the plane of polarisation of the sampled beams and detector means therefor, and an electronic phasemeter for measuring the difference between the two beat frequency signals generated by the detector means.

4. Apparatus as in Claim 3, wherein the divergent beams are focussed by a lens.

5. Apparatus as in Claim 4, wherein the lens is disposed before the pair of dichroic filters.

6. Apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

7. Apparatus for continuously measuring the optical retardation of synthetic filaments in an advancing threadline or of an advancing synthetic film substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

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